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A NEW RELAYING PRINCIPLE FOR TRANSFORMER OVERLOAD PROTECTION

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Abstract A new approach to transformer overload protection is proposed, one based on temperature rather than current. A big advantage of the idea is that such things as ambient temperature, current waveform, and several other parameters are automatically taken into account. A further advantage is that emergency overload conditions are also automatically handled, without immediate operator intervention when the emergency occurs.

Introduction

The commonly used *inverse-time overcurrent* protective relay has the familiar shape shown in Fig. 1.

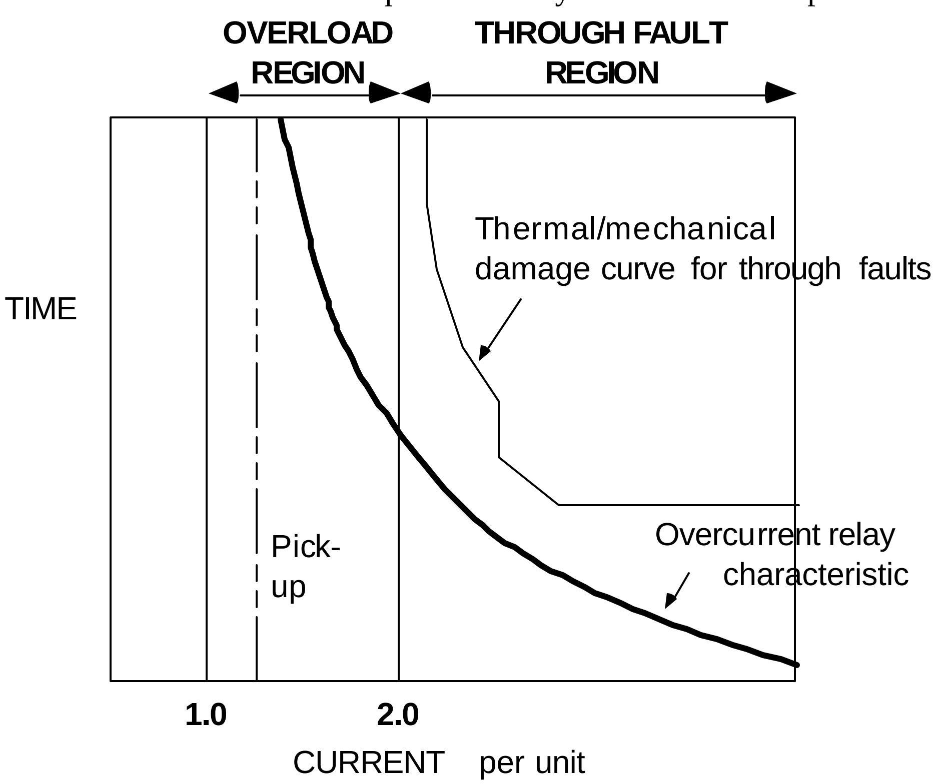

Fig. 1 Commonly used inverse time characteristic.

This type of protection tries to cover two distinct damage regions: **overload** damage, and **through-fault** damage.

In the **through-fault region** there is both **thermal** and **mechanical** damage. This damage is avoided by judicious placement of the relay characteristic curve, as shown in the figure.

In the **overload region** it is interesting to examine the cause-effect relationship between **overcurrent** and **insulation damage** which is, after all, the reason for this protection:

$$\text{overcurrent} \longrightarrow \text{heat} \longrightarrow \text{temperature} \longrightarrow \text{insulation damage.}$$

However, the relationship is not that simple. There are other parameters:

$$\left.\begin{array}{l} \text{overcurrent} \\ + \text{ ambient temp} \\ + \text{ pre-loading} \\ + \text{ sunshine} \\ + \text{ rain} \\ + \text{ cooling method} \\ + \text{ current waveform} \end{array}\right\} \text{heat} \longrightarrow \text{temperature} \longrightarrow \text{insulation damage,}$$

Therefore, it would make sense to base this protection function on a variable “closer to the problem,” specifically the **temperature**:

$$\text{temperature} \longrightarrow \text{insulation damage,}$$

a much more direct indication of this problem.

Which temperature is implied?

Obviously it should be the **winding temperature**, sometimes called the ‘hot spot temperature.’

How is winding temperature measured?

The use of fiber-optic sensors is expensive, delicate, and it is argued here: unnecessary. [By analogy, it would be impractical to install force-sensing devices next to the windings to try to measure the mechanical damage conditions.]

The reason that temperature sensors are unnecessary is that the **winding temperature can be calculated** quite accurately, either from known ambient temperature as a starting point, or known top oil temperature, an even better starting point. The ambient temperature can be measured (by the relay) by means of an attached sensor running just outside the relay building, whereas the top oil temperature would require a signal from the transformer in question.

Should there be an 'maximum temperature alarm?

Yes, there should be an absolute value of winding temperature beyond which the device should never be allowed to go, however short the time: perhaps 140°C. This is either a manufacturer-specified 'bubble formation temperature' or a judgment of the user.

What level of winding temperature should cause a loss-of-life alarm?

This is where the idea of **inverse time** should come in. In accordance with IEEE/ANSI Standards[1], large oil-immersed power transformers can withstand high temperatures for short times, and lower temperatures for longer times. The criterion has to do with how much **loss of life** one is willing to tolerate, over say one day.

Implementation

The first part of this argument is that the through-fault-current aspect should be **separated** from the overload aspect**.** The **fault current** aspect is taken care of by an overcurrent inverse time curve with a fixed pickup setting of **two** per unit, as shown in Fig. 2.

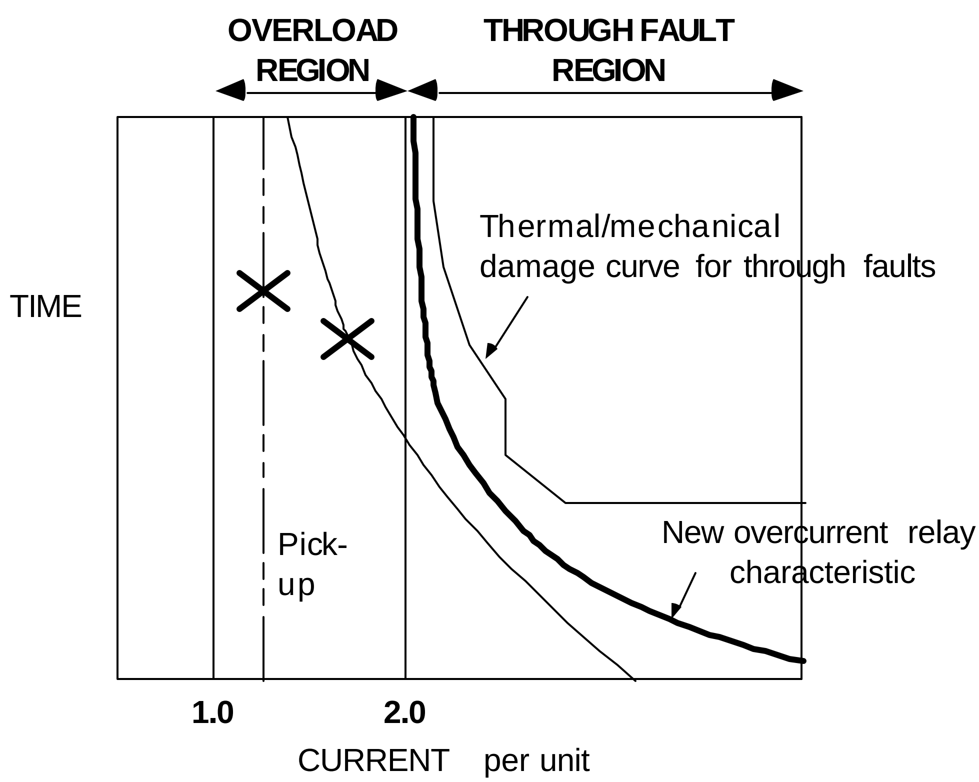

Fig. 2. Inverse time overcurrent **through-fault** protection.

The **overload** aspect is covered by what might be called an *inverse time overtemperature* curve, as shown in Fig. 3. Its basis is taken from an ANSI/IEEE Standard [1]. The idea in that Standard, and one used by some utilities as an overloading guideline is that

> a temporary overload should be such that the 'loss of life' during the overload period is limited to a certain multiple of the normal loss of life for that whole day. The multiple might be one, two, four, eight, etc. depending on an engineering judgment call.

The particular inverse time curve shown in Fig. 3 is for "twice normal rate of loss of life," i.e. the curve labeled "2" in Fig. 4.

The way in which the inverse time curve is realized (in software) is similar to the way it is accomplished for an inverse time overcurrent relay - namely that a particular temperature level sets an integration rate that makes the relay proceed toward 'trip' (alarm, in this case) such that it will time out in the proper time. In this way, if the temperature varies during the process, the operation is still logical, i.e. the higher the temperature, the faster the rate of progress toward the alarm condition.

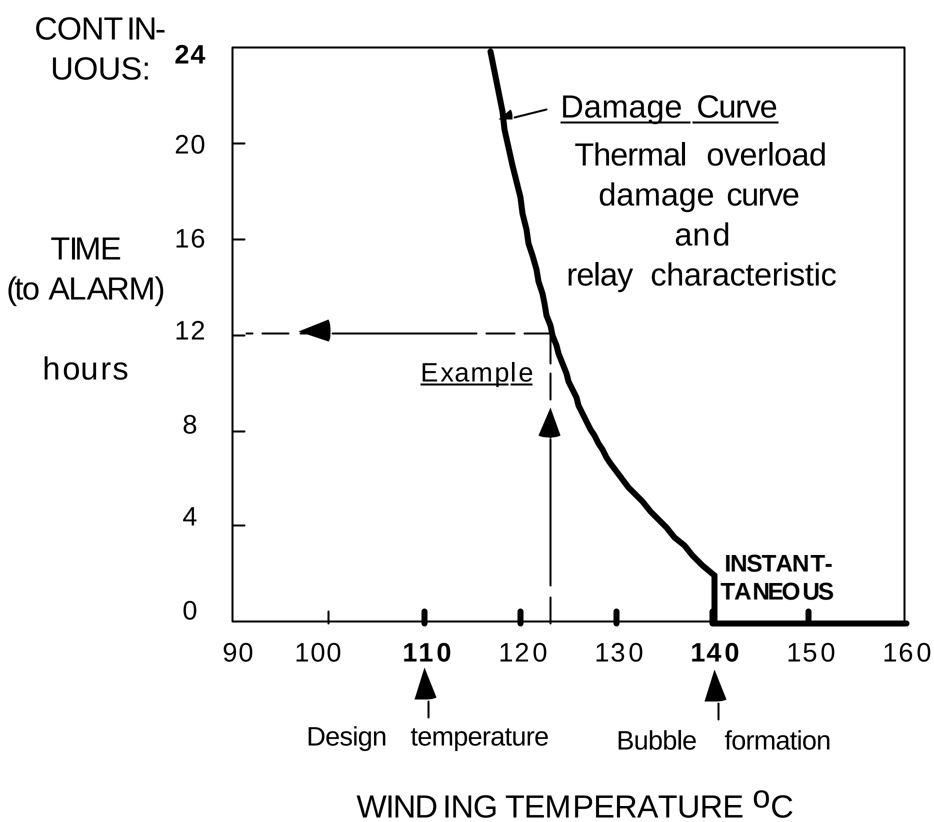

Fig. 3. Inverse time **overtemperature** protection.

The sample SETTINGS display is shown in Fig.4.

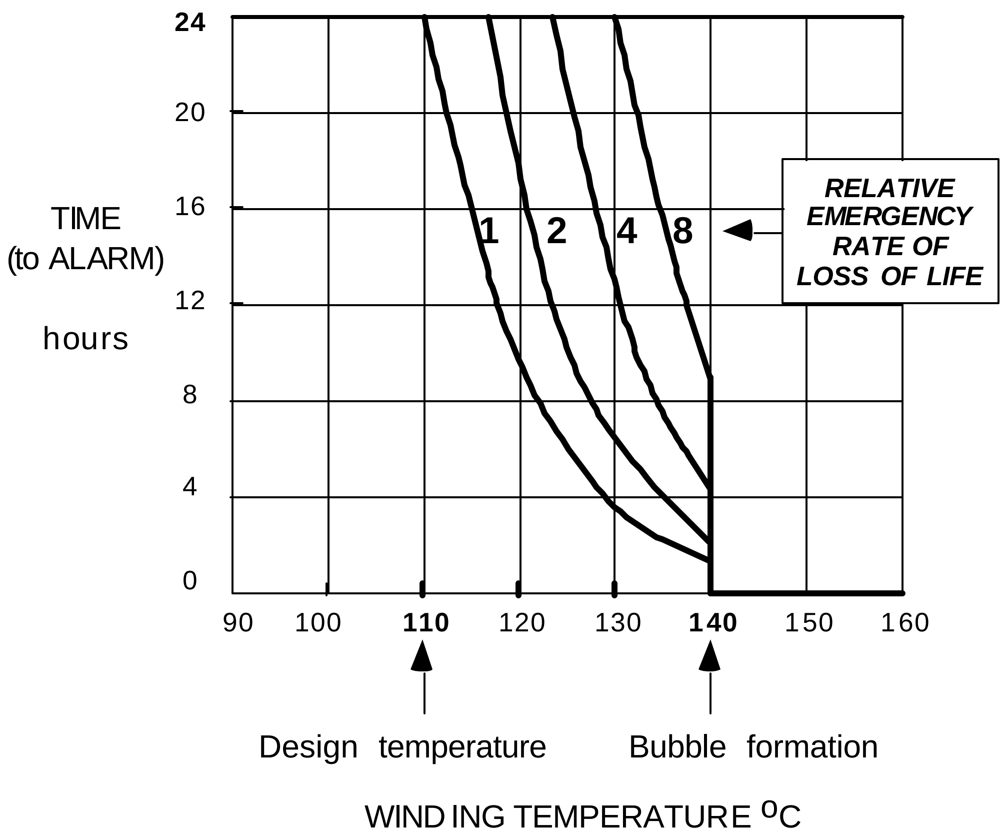

Fig. 4. Settings display for the **inverse time overtemperature** protection.

Note that there is only ONE setting, a value judgment in fact, for the acceptable 'emergency rate of loss of life.' Two other defining values - the **design temperature** and the **bubble formation temperature** - are not settings; they are input parameters similar to the transformer rating, cooling method, etc.

<u>One final consideration</u> is the fact that the present inverse-time relay curve between 1.0 and 2.0 per unit provides some back-up to the system, for faults far out on a feeder, for example. It could be possible to recognize such currents as fault currents - as opposed to overload currents - by supervising the trip with the phase angle of the current with respect to the voltage (around zero degrees for load current, -70 degrees for fault current).

Conclusions

An **inverse time overtemperature** concept is presented, as a useful concept to help operators under emergency conditions.

The advantages are:

- Parameters other than current, such as ambient temperature and current waveform, are automatically taken into account in determining the overloading damage.
- Short term emergency overloading is also taken into account.
- Information for the engineer is available in terms of plots versus time of loading, ambient temperature, top oil temperature, winding temperature, loss of life and rate of loss of life, over both short and long periods.

References

1. ANSI/IEEE Standard C57.115-1991, "Loading of Mineral-Immersed Power Transformers Rated in Excess of 100 MVA."

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Biography of the presenter

Glenn Swift studied electrical engineering at the University of Alberta and the Illinois Institute of Technology. He has worked for several manufacturing firms, including Federal Pioneer Ltd. and Westinghouse Canada. He was a professor at the University of Manitoba for 36 years and is currently Director of Research and Development for Alpha Power Technologies.